

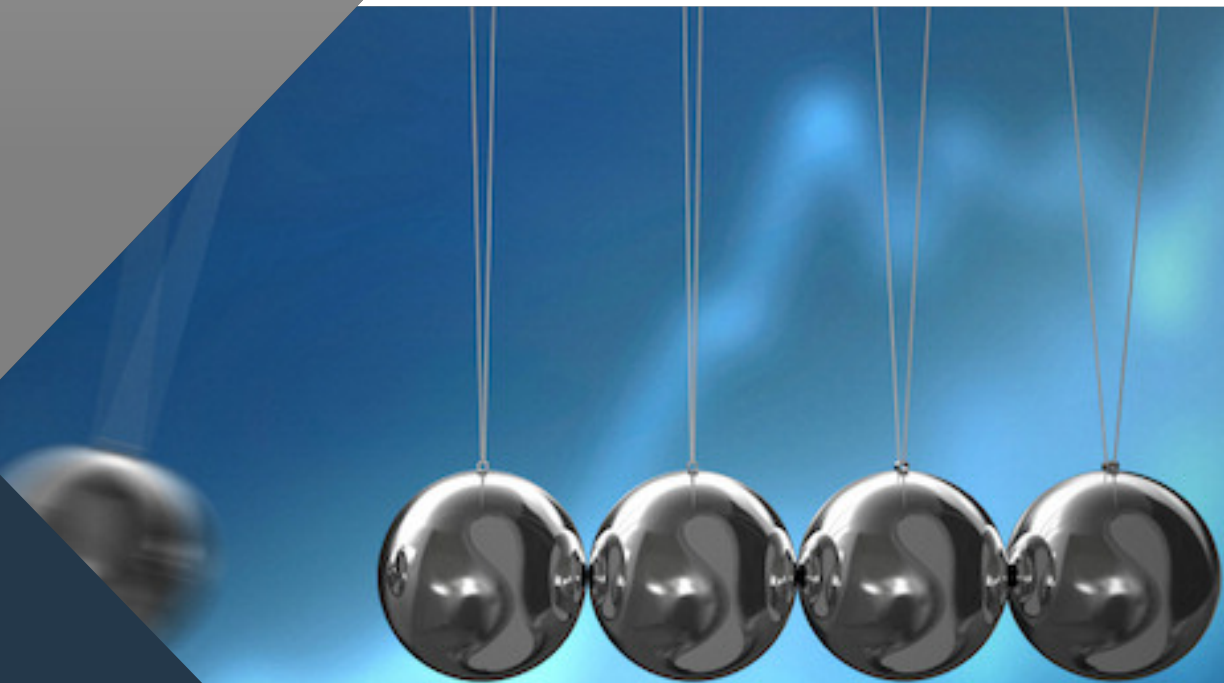


**A Textbook of Engineering**

# **PHYSICS-I**

**As Per the Latest Syllabus of Diploma in Engineering Courses under  
Jharkhand University of Technology, Ranchi**

**Dr. Pankaj Kumar**



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# A Textbook of Engineering Physics – I

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*As per the latest syllabus of  
Diploma in Engineering Courses Under  
Jharkhand University of Technology, Ranchi*

*by*

**Dr. Pankaj Kumar, Ph.D.,**  
*Lecturer in Physics*  
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**KHANNA PUBLISHERS®**

*Operational Office : Investing in Learning®*  
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Ground Floor, Daryaganj, New Delhi 110 002  
*Phones : 011-45033819 • Mob. 09811541460*  
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(ii)

**Published by :**

Romesh Chander Khanna & Vineet Khanna  
for **KHANNA PUBLISHERS**  
2-B, Nath Market, Nai Sarak,  
Delhi-110006 (India)

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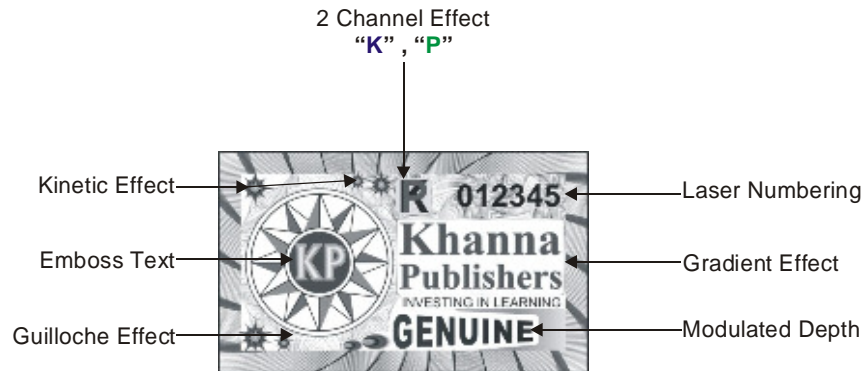
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**ISBN No. : 978-93-87394-73-5**

**Second Edition : 2021**

*Dedicated to  
My  
Beloved Mother and Father*



## **Jharkhand University of Technology**

Science & Technology Campus, Sirkha Toli, Namkum, Ranchi – 834010 (Jharkhand)

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Letter No.:- JUT/224/2019/466

/Ranchi, Date:-19-06-2019

### **Foreword**

A Text Book of Engineering Physics-I written by Dr. Pankaj Kumar, is indeed a book, which will help the Diploma Engineering students of various Colleges affiliated to the Jharkhand University of Technology, Ranchi and other colleges too. The book covers almost all the aspects of Physics, which are taught by any eminent teacher in the class. In a way, it will help the students in clearing their concepts of Physics. It contains the Objective and Subjective questions and their answers as well as Numerical problems of different kinds.

I wish that the book gains a great success.

*Gopal Pathak*

**Prof. (Dr.) Gopal Pathak**  
Vice-Chancellor

Jharkhand University of Technology,  
Ranchi

# *Preface to the Second Edition*

---

I have received comments, suggestions, and corrections from students and teachers of Jharkhand. I thank them, their suggestions have helped me to revise this book.

In this second edition, I have tried to correct the misprints to my level best.

Special feature of this second edition is that I have added **Previous Year Question Paper of 1st semester Engineering Physics-I of Jharkhand University of Technology, Ranchi.**

For student's convenience, I have added two set of **Model Question Paper** for 1st semester of Engineering Physics-I for JUT examination purpose on the huge demand of students.

I have tried to make simpler the chapter **Work, Power and Energy** for students.

I am grateful to editorial team of Khanna Publishers, especially Mr. Kumar Sandeep, National Marketing Manager for their continued interest to this project.

I am looking forward and hope I will get suggestions and comments from students and teachers in making this book more useful to the students.

—Pankaj Kumar (Ph.D)

# Reviews

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I had opportunity of reviewing the book “A Text Book of Engineering Physics-I”. Each topic is discussed in a simple, yet deeply penetrating fashion. The author has kept in mind the needs of those readers who wish to obtain a thorough knowledge of the subject without any guide. The student will find this book to be of great help in improving their knowledge of physics at Diploma Engineering for 1st Semester of Jharkhand University of Technology, Ranchi. This book deserves to become popular and carries all the features to serve as a Text Book at the Diploma Engineering level.

Dr. C. N. Mishra, *Ex-Head(Retd.)*  
University Department of Physics  
Kolhan University, Chaibasa (Jharkhand)

\*\*\*\*\*

*This book has been written keeping in mind the syllabus of Jharkhand University of Technology, especially for 1st Semester Diploma Engineering course. It would serve as a useful textbook for the subject of Physics. There are a number of books available in the market on the Physics related to the Diploma Engineering course; however the treatment given in them is not in depth. To overcome this problem, this book looks a lucid style and presented the concept and necessary mathematical formulations in a comprehensive manner. In this book, the author eternally analyzed the recent examples. The solutions were discussed as the route cause problems in detailed and the course of action for solutions were established. This is certainly the most critical aspect of the book. The author's style is fluent however it will have to go through extensive editorial revisions. The several universities are actively considering the Physics a course in Diploma Engineering. This book would be suitable for such a course since this is too general and detailed enough.*

Dr. T. P. Yadav, *Scientist*  
Department of Physics  
Institute of Science,  
Banaras Hindu University, Varanasi

\*\*\*\*\*

It gives me immense pleasure to get the opportunity of reviewing the book “A Text Book of Engineering Physics-I”. It covers entire the syllabus of Diploma Engineering for Ist Semester of Jharkhand University of Technology, Ranchi. I complement the author and appreciate his efforts to bring out this text book in a very simple language. The text is comprehensive and explanation of topics is commendable. Multiple Choice Questions with Answers, Short Type Questions, Long Type Questions Solved and Unsolved numerical problems at the end of each chapter are designed to probe a student's grasp of concepts thought in the text. I understand that this book carries all the elements required for a good presentation.

Aftab Alam  
*Senior Lecturer & In-charge,*  
Deptt. of Engg. Physics  
Al-Kabir Polytechnic, Jamshedpur

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# 1

## CHAPTER

## Units and Measurements

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### LEARNING OBJECTIVES

After reading this chapter, the student will be able to

- Understand the need of measurement in science and engineering and principles of units and homogeneity of dimensions.
- Know the some basic terms such as physics, fundamental physical quantity, fundamental and derived units, dimensions, accuracy, precision, errors, percentage error.
- Utilize the use of dimensional equations and to check the correctness of error in measurement
- Develop an understanding about dimensions of physical quantities and significant figures.

### PHYSICS

**Physics** is the most basic science of the living and non-living Sciences which deals with nature and natural phenomenon. All other Sciences are built on the knowledge of physics. Mathematics is the language of physical Science.

In Science a fact is just a close agreement by competent observers who make a series of observations of the same phenomenon. A hypothesis is an educated guess that is only presumed to the factual until verified or contradicted through experiments. When hypotheses are tested repeatedly and not contradicted, they may be excepted as fact and then known as **laws** or **principles**.

If a scientists finds evidence that contradicts a law, hypothesis or principle then that law, hypothesis or principle must be changed to fit the new data or abandoned if it can not be changed.

A **theory** is must like a hypothesis in that it generally indicates something that has yet to be verified. In Science a theory is instead the result of well-tested and verified hypotheses about the reasons for certain observed behaviours. Theories one refined as new information is obtained.

Science and engineering are based on measurements and comparisons. Science works according to the scientific method. The scientific method accepts only reason, logic and experimental evidence to differentiate between what is scientifically correct and what is not. The real strength of physics *i.e.*, science lies in the fact that it continuously keeps challenging itself.

Physics is the most fundamental scientific discipline and its main goal is to understand how the universe behaves.

## NEED OF MEASUREMENT AND UNIT

Science and engineering are based on observations. Measurement is the process of comparing of an unknown quantity with standard one. Whereas the instrument is a device used for comparing the unknown physical quantity with standard quantity of same nature.

## PHYSICAL QUANTITY

**“All the quantities which can be measured are called physical quantity”.** For example, mass, length, time, velocity etc.

**Unit : “The standard used to measure a physical quantity is known as unit”.**

For example, when we say that a distance is equal to 5 meter, it means that meter is the standard or unit which is contained 5 times in that distance and 5 is the numerical value. Thus the numerical value alongwith the standard *i.e.*, unit is needed to completely express a physical quantity.

If  $q$  = physical quantity  
 and  $n$  = numerical value of physical quantity  
 then,  $u$  = standard or unit of physical quantity

$$q = nu$$

*i.e.*, Magnitude of physical quantity

= Numerical value of physical quantity × standard or unit of physical quantity

## PROPERTIES OF UNIT

A unit selected to measure a physical quantity must possess the following properties:

1. They must be well defined
2. They should be easily available and reproducible.
3. They should not vary with time and space.
4. They should be accepted internationally.

## REQUIREMENTS OF STANDARD OR UNIT

There are various units for measuring same physical quantities in different countries. Physical quantities like length has been measured in meter, centimeter, foot, yards etc. Similarly mass has been measured in kilograms, grams, pound etc. It was necessary to come up with a certain system of unit which can be accepted and used all over the world.

### Fundamental and Derived Units:

**FUNDAMENTAL UNIT:** Those physical quantities which are independent of each other and can be explained independently are known as fundamental quantities and their respective units are known as fundamental or base units.

**DERIVED UNIT:** Those physical quantities which can be explained with the help of fundamental quantities, are known as derived quantities and their respective units are known as derived units.

For example, the physical quantity velocity is derived or explained with the help of displacement *i.e.*, length and time

$$i.e., \quad \text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{\text{Length}}{\text{Time}} = \frac{\text{m}}{\text{s}} = \text{ms}^{-1}$$

Hence velocity is derived physical quantity and its unit m/s is derived unit.

### SYSTEMS OF UNITS

There are four systems of unit namely C.G.S. system, F.P.S. system M.K.S. system and S.I. system.

**C.G.S. System :** In this system

C – Stands for **centimeter**

G – Stands for **gram**

S – Stands for **second**.

In this system physical quantities, length mass and time are measured in centimeter, gram and seconds respectively.

**F.P.S. System :** It is a British system of unit in which

F – Stands for **foot**

P – Stands for **pound**

S – Stands for **second**.

In this system the physical quantities length, mass and time are measured in foot, pound and seconds respectively.

**M.K.S. System :** This system was set up in France in which

M – Stands for **meter**

K – Stands for **kilogram**

S – Stands for **second**.

This system is closely related to C.G.S. system.

In this system physical quantities length, mass and time are measured in meter Kilogram and second.

### INTERNATIONAL SYSTEM OF UNITS (S.I. SYSTEM)

This system is the modified form of M.K.S. system and is accepted all over the world. This system includes seven fundamental quantities such as length, mass, time, temperature, current electricity, luminous intensity and amount of substance.

#### Fundamental Quantities with their Units

<i>S.No.</i>	<i>Name of Physical Quantity</i>	<i>Unit</i>	<i>Abbreviations Symbol</i>
1.	Length	Meter	m
2.	Mass	Kilogram	kg
3.	Time	Second	s
4.	Electric current	Ampere	A
5.	Temperature	Kelvin	K
6.	Luminous intensity	Candela	Cd
7.	Amount of substance	Mole	mol

Besides the seven fundamental physical quantities and their respective fundamental units there are two supplementary physical quantities and their respective units.

### Supplementary Physical Quantities and their Units

<i>S.No.</i>	<i>Name of Physical Quantities</i>	<i>Unit</i>	<i>Abbreviation/Symbol</i>
1.	Plane angle	Radian	Rad
2.	Solid angle	Steradian	Sr.

### SI PREFIXES

The magnitudes of physical quantities vary over a wide range. Following are the S.I. prefixes

<i>Powers of 10</i>	<i>Prefix</i>	<i>Symbol</i>
18	exa	E
15	peta	P
12	tera	T
9	giga	G
6	mega	M
3	kilo	K
2	hecto	h
1	deka	da
- 1	dece	d
- 2	centi	c
- 3	milli	m
- 6	micro	$\mu$
- 9	nano	n
- 12	pico	p
- 15	femto	f
-18	atto	a

### DEFINITIONS OF FUNDAMENTAL UNITS

We briefly mentioning the definitions of the fundamental units as follows:

**Metre :** It is the unit of length. The distance travelled by light in  $\frac{1}{299,792,458}$  second is called 1 meter.

**Kilogram :** One kilogram is the mass of a cylinder made of platinum-iridium alloy kept at the International Bureau of weights and measure at severes near Paris (France).

**Second :** One second is the time taken by light of specified wavelength emitted by a Cs – 133 (cesium – 133) atom to execute 9, 192, 631, 770 vibrations.

**Ampere :** The ampere is that current which when move in each of the two straight parallel conductors of infinite length and negligible cross-section placed one meter apart in vacuum produces a force of  $2 \times 10^{-7}$  N/m between the conductors.

**Kelvin :** One kelvin is  $\frac{1}{273.16}$  of the thermodynamical temperature of the triple point of water.

**Candela :** The Candela is the Luminous intensity of a black body of surface area  $\frac{1}{6,00,000}$  square meter placed at the temperature of freezing platinum and at pressure of 101, 352 Nm<sup>-2</sup> perpendicular to its surface.

**Mole :** One mole is the amount of substance that contains as many elementary entities (atoms or molecules) as there are atoms in 0.012 kg of pure carbon – 12 (C – 12) and this number is called Avogadro's number and its value is  $6.023 \times 10^{23}$ .

**Radian:** One radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the Circle.

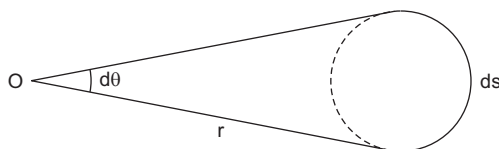


Fig. 1.1.

$$d\theta = \frac{ds}{r} \text{ radian}$$

where,  $ds$  = arc of the length

and  $d\theta$  = angle subtended at the centre of a circle,  $r$  = radius of the circle.

**Steradian :** The steradian is the solid angle subtended at the centre of the sphere by an area of its surface equal to the square of the radius of the sphere.

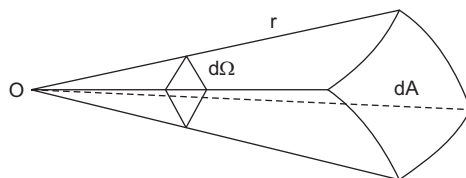


Fig. 1.2.

$$d\Omega = \frac{dA}{r^2}$$

where,  $d\Omega$  = Solid angle

$dA$  = area of spherical surface

$r$  = radius of the sphere.

## SOME PRACTICAL UNIT

### (a) Macrocasm measurement (very large distance) :

- 1. Astronomical unit (AU):** It is the average distance of the centre of the Sun from the centre of the Earth.

$$1\text{AU} = 1.496 \times 10^{11} \simeq 1.5 \times 10^{11} \text{ m}$$

- 2. Light year (LY):** One light year is the distance travelled by light in the free space in one year. The velocity of light in vacuum ( $c$ ) =  $3 \times 10^8 \text{ ms}^{-1}$ .

$$\therefore 1 \text{ Year} = 365 \times 24 \times 60 \times 60 \text{ second}$$

$$\therefore 1 \text{ Light Year} = V \times t$$

or,  $1 \text{ Light Year} = 3 \times 10^8 \times 365 \times 24 \times 60 \times 60 \text{ m}$   $\{\because t = 365 \times 24 \times 60 \times 60 \text{ S}\}$   
 or  $1 \text{ LY} = 9.46 \times 10^{15} \text{ m}$

**Par Sec :** One par sec is the radius of a circle at the centre of which on an arc of the circle, 1 AU long subtends an angle  $1''$ .

$$1 \text{ par sec} = 3.1 \times 10^{16} \text{ m}$$

$$1 \text{ par sec} = 3.26 \text{ Ly} \quad \{\because 1 \text{ LY} = 9.46 \times 10^{15} \text{ m}\}$$

(a) **Some useful units of length:**

$$1 \text{ inch} = 0.0254 \text{ m}$$

$$1 \text{ foot} = 0.3048 \text{ m}$$

$$1 \text{ yard} = 0.9144 \text{ m}$$

$$1 \text{ mile} = 1.609 \times 10^3 \text{ m}$$

$$1 \text{ nautical mile} = 1.82 \times 10^3 \text{ m}$$

(b) **Micro-Cosm measurement (very small distance):**

$$1 \text{ micron } (\mu) = 10^{-6} \text{ m}$$

$$1 \text{ nanometer (nm)} = 10^{-9} \text{ m}$$

$$1 \text{ angstrom } (\text{\AA}) = 10^{-10} \text{ m}$$

$$1 \text{ fermi (fm)} = 10^{-15} \text{ m}$$

(c) **Measuring heavy masses:**

$$1 \text{ tonne or 1 metric ton} = 10^3 \text{ kg}$$

$$1 \text{ quintal} = 100 \text{ kg}$$

$$1 \text{ slug} = 14.57 \text{ kg}$$

**Chandra Shekhar Limit (C.S.L.)** is the largest practical unit of mass

$$1 \text{ C.S.L.} = 1.4 \text{ times of mass of the Sun}$$

$$= 1.4 \text{ solar mass} = 1.4 \times 1.989 \times 10^3 \text{ kg}$$

(d) **Lunar month:** The time taken by the moon to complete one revolution around the earth in its orbit.

$$i.e., \quad 1 \text{ Lunar month} = 27.8 \text{ days}$$

(e) **Shake:**

Shake is the smallest unit of time

$$1 \text{ shake} = 10^{-8} \text{ second} = 10 \text{ nano seconds.}$$

## ADVANTAGES OF SI UNITS

The SI system of units has following advantages:

- It is closely related to the MKS system of unit.
- In SI system, only one unit is used for one physical quantity. Therefore, it is rationalised system of units.
- All derived units can be obtained by suitable manipulation of base and supplementary units and no numerical factors are encountered, therefore, it is a coherent system of units.
- In SI system, multiples can be expressed as suitable powers of 10.

## DIMENSIONS

The unit of mass, length and time are denoted by the capital letters [M], [L] and [T] which merely indicate their nature and not their magnitude. Since the unit of area is the product of two unit lengths, We have the unit of area represented by

$$[L] \times [L] = [L^2]$$

and Similarly, the unit of volume being the product of three unit of lengths is represented by

$$[L] \times [L] \times [L] = [L^3]$$

We express this by saying that the unit of area has two dimensions in length and the unit of volume has three dimensions in length. Since neither the unit of area nor that of volume depends upon mass and time, their dimensions are said to be zero in both mass and time and we may therefore, represent these units as  $[M^0 L^2 T^0]$  and  $[M^0 L^3 T^0]$  respectively.

Thus the dimensions of a physical quantity are the powers to which the fundamental units of mass, length and time are to represent it.

Thus if a derived unit depends upon the  $n$ th power of a fundamental unit, then it is said to be of  $n$  dimensions in that fundamental unit.

For example,

$$\text{Velocity} = \frac{\text{Displacement or Length}}{\text{Time}} = \left[ \frac{L}{T} \right] = [L T^{-1}]$$

Therefore, the dimensions of the velocity are 1 in length and  $-1$  in time. Since it is independent of mass, its dimension in mass is zero and we may therefore represent it by  $[M^0 L T^{-1}]$ . Again since acceleration =  $\frac{\text{Velocity}}{\text{Time}}$  the dimensions of the unit of acceleration are

$$\frac{[M^0 L T^{-1}]}{[T]} = [M^0 L T^{-2}]$$

## DIMENSIONAL FORMULAE AND EQUATIONS

A dimensional formula is an expression showing how and which of the fundamental units enter into the unit of a physical quantity”.

**The relation between the physical quantity and the fundamental quantities expressed in the form of equation is called dimensional equation.**

For example, the dimensional formula of work is  $[ML^2 T^{-2}]$ . But when we put it in the form,  $W = [ML^2 T^{-2}]$ , it is called a dimensional equation of work.

## PRINCIPLE OF HOMOGENEITY

**According to the principle of homogeneity “a physical relation is dimensionally correct if the dimensions of fundamental quantities are the same in each and every term on either side of the equation”.**

This principle basically signifies that only similar physical quantities can be added, subtracted or equated.

For example, we consider the following relation:

$$s = ut + \frac{1}{2} at^2$$

Here,  $s$  = displacement

$u$  = initial velocity

$t$  = time interval

$a$  = uniform acceleration.

The dimensions of each term of both side are as follows:

$$\begin{aligned} \text{Dimension of 's'} &= [M^0LT^0] \\ \text{Dimension of 'ut'} &= [M^0LT^{-1}] \times [M^0L^0T] = [M^0LT^0] \\ \text{Dimensions of 'at}^2\text{' } &= [M^0LT^{-2}] \times [M^0L^0T^2] = [M^0LT^0] \end{aligned}$$

$$\therefore s = ut + \frac{1}{2} at^2$$

$$\text{or} \quad [M^0LT^0] = [M^0LT^0] + [M^0LT^0] \quad \left[ \because \frac{1}{2} \text{ has no dimension} \right]$$

$$\text{or} \quad [M^0LT^0] = [M^0LT^0] = [M^0LT^0] \quad [\because 2 \text{ has no dimension}]$$

Since dimension on R.H.S. are the same as that on L.H.S. therefore the relation is dimensionally correct.

If a physical relation is not dimensionally homogeneous, then the equation is incorrect.

### DIMENSIONLESS QUANTITIES

**“Some quantities are ratios comparing one quantity with the other of the same kind and their numerical values are independent of the system of units chosen, they are known as dimensionless quantities”.**

For example, specific gravity, strain in elasticity, refractive index etc.

Longitudinal strain is defined as the ratio of increase in length to the original length.

Therefore,

$$\text{Strain} = \frac{\text{Increase in length}}{\text{Original length}} = \frac{l}{L}$$

$$\therefore \text{Strain} = [L^0]$$

$\therefore$  Dimensionless quantity this indicates that strain is a pure number and hence it is dimensionless.

### USES OF DIMENSIONAL EQUATIONS

The following are the uses of dimensional equations:

- To check the correctness of an equation.
- To convert unit of one system into another.
- To restate a forgotten formula.
- To derive relationship between different physical quantities.

**(a) TO CHECK THE CORRECTNESS OF A EQUATION:** To check the correctness of the given equation,

We shall write the dimensions of the equations of the quantities of both the sides of the equation.

For example,

$$T = 2\pi \sqrt{\frac{l}{g}}$$

Here,  $T$  = time period

$l$  = length of pendulum

$g$  = acceleration due to gravity

Now, Dimensions of 'T' = [T] = [M<sup>0</sup>L<sup>0</sup>T]  
 Dimensions of 'l' = [L] = [M<sup>0</sup>L<sup>1</sup>T<sup>0</sup>]  
 Dimensions of 'g' = [LT<sup>-2</sup>] = [M<sup>0</sup>L<sup>1</sup>T<sup>-2</sup>]

$$\therefore [M^0L^0T] = \sqrt{\frac{[M^0LT^0]}{[M^0LT^{-2}]}} \quad [\because 2\pi \text{ is dimensionless}]$$

or,  $[M^0L^0T] = \sqrt{T^2} = [T]$

or,  $[M^0L^0T] = [M^0L^0T]$

Since the dimensions of L.H.S. is equal to the dimensions of R.H.S. Thus, the given relation is correct.

**(b) TO CONVERT UNIT OF ONE SYSTEM INTO ANOTHER:** The conversion of one system of unit into another unit is based on the fact that magnitude of a physical quantity remains the same whatever be the system of its measurement.

Let us suppose, we have a physical quantity Q. Let n<sub>1</sub> and n<sub>2</sub> be numerical values of the physical quantity when measured in the two systems having size of units u<sub>1</sub> and u<sub>2</sub> respectively then,

$$\begin{aligned} Q &= n_1 u_1 && \text{first system of unit} \\ \text{and} \quad Q &= n_2 u_2 && \text{Second system of unit} \\ \therefore Q &= n_1 u_1 = n_2 u_2 \end{aligned}$$

Let the physical quantity Q has the dimensional formula [M<sup>a</sup>L<sup>b</sup>T<sup>c</sup>].

Let M<sub>1</sub>, L<sub>1</sub> and T<sub>1</sub> are the fundamental units of mass, length and time in the one system of unit and M<sub>2</sub>, L<sub>2</sub> and T<sub>2</sub> are the fundamental units of mass, length and time in second system of unit. Then,

$$\begin{aligned} Q &= n_1 [M_1^a L_1^b T_1^c] && \text{in first system of unit} \\ \text{and} \quad Q &= n_2 [M_2^a L_2^b T_2^c] && \text{in second system of unit} \\ \therefore n_1 [M_1^a L_1^b T_1^c] &= n_2 [M_2^a L_2^b T_2^c] \\ \therefore n_2 &= n_1 \left[ \frac{M_1^a}{M_2^a} \frac{L_1^b}{L_2^b} \frac{T_1^c}{T_2^c} \right] = n_1 \left[ \frac{M_1}{M_2} \right]^a \left[ \frac{L_1}{L_2} \right]^b \left[ \frac{T_1}{T_2} \right]^c \end{aligned}$$

Therefore, if we know the value of a physical quantity in one system of units, we can find its value in the other system of units.

**(c) TO RESTATE A FORGOTTEN FORMULA:** If the physical quantities involved in a relation are known but the powers of these physical quantities are not known then we can use the principle of homogeneity of dimensions to obtain the correct relation.

For example a relation is written as

$$F = 4\pi^2 fmr$$

where, F = force

f = frequency,

m = mass

and r = radius.

If we want to know the powers of f, m and r in the above equation, then principle of homogeneity of dimensions is applied.

Let us suppose  $f$ ,  $m$  and  $r$  have the powers  $a$ ,  $b$  and  $c$  respectively.

By equating the dimensions of M, L and T of the two sides of the relation. We can find the values of  $a$ ,  $b$  and  $c$ .

$$\text{Dimensions of L.H.S.} = [F] = [MLT^{-2}]$$

On the R.H.S.,  $4\pi^2$  has no dimension, therefore only  $f$ ,  $m$  and  $r$  are enter into dimensional equation.

$$\therefore \text{Dimensions of R.H.S.} = [T^{-1}]^a [M]^b [L]^c \quad \left\{ \because f = \frac{1}{T} \right\}$$

For equation to be correct, the dimensions of M, L and T on equal the two sides must be the equal *i.e.*,

$$[MLT^{-2}] = [M]^b [L]^c [T^{-1}]^a$$

Equating the powers of M, L and T on both the sides, we have,

$$a = 2, b = 1, c = 1$$

$$\therefore \text{Correct equation is } F = 4\pi^2 f^2 m r$$

**(d) TO DERIVE RELATIONSHIP BETWEEN DIFFERENT PHYSICAL QUANTITIES:**

If we know the factors upon which a given physical quantity depends, we can find the relation between the physical quantities.

For example, let us suppose that we want to deduce an expression for the time period of a simple pendulum.

The factors on which the time period T may depend upon

- (i) Mass of the bob,  $m$
- (ii) Length of the pendulum,  $l$
- (iii) Acceleration due to gravity,  $g$  and
- (iv) Angle of swing,  $\theta$

$$\text{Let } T = K m^x l^y g^z \theta^w \quad \{K = \text{Constant}\}$$

Putting dimensions both the sides we can write

$$[M^0 L^0 T] = [M]^x [L]^y [LT^{-2}]^z \quad (\theta \text{ is omitted as it does not have any dimension and constant } k \text{ is dimension Less})$$

Now equating the indices both the sides, we have,

$$x = 0;$$

$$y + z = 0 \quad \text{and} \quad -2z = 1$$

$$\therefore z = -\frac{1}{2} \quad \text{and} \quad y = \frac{1}{2}$$

$$\text{Therefore, } T = k l^{1/2} g^{-1/2}$$

$$\therefore T = k \sqrt{\frac{l}{g}}$$

The value of  $k$  is found out experimentally to be equal to  $2\pi$

$$\therefore \text{Time period, } T = 2\pi \sqrt{\frac{l}{g}}.$$

**LIMITATIONS OF DIMENSIONAL ANALYSIS**

Dimensional analysis though seems to be very helpful, but it has its own limitations. The drawbacks are

- (i) It gives no information or a little information about pure numerics and dimensional quantities involved in various physical relations. They are to be determined by some other ways may be by calculation or by experiment.
- (ii) It is restricted solely to physical relationships which are power functions. Relationships involving exponential or trigonometrical functions are not dealt with.
- (iii) Dimensions of some physical quantities may not represent the same thing. For example, moment of force and work have the same dimension but they are entirely different quantities. The former being vector and the other is scalar.
- (iv) This dimensional analysis is of no use in deciding the exact form of a physical relation which depends on more than three quantities.

**True value :** “The true value of a measurement is the value obtained by a perfect measurement”.

The true value is obtained after an infinite series of measurements performed under same conditions with an instrument without systematic errors.

**Measured value :** “A measured value is the value of an object being measured, provided by a measuring instrument or measuring device”. It is expressed as the product of numerical value and the unit”.

**Accuracy :** “The accuracy of a measurement is a measure of how close the measured value is to the true value of a physical quantity”.

**Precision :** Precision describes the limitation of the measuring instrument. It is determined by the least count of the measuring instrument. Smaller the least count, greater is the precision of the measuring instrument. Precision is independent of accuracy.

### Accuracy vs. Precision

Accuracy describes how close a measured value is to the true value of the quantity being measured problems with accuracy one due to error.

To avoid error–

- (a) Take repeated measurements to be certain that they are consistent (avoid human error).
- (b) Take each measurement in the same way (avoid method error).
- (c) Be sure to use measuring equipment in good working order (avoid instrument error).

**Precession** refers to the degree of exactness with which a measurement is made and stated.

- (a) 1.592 is more precise than 1.5 m
- (b) lack of precision is usually a result of the limitations of the measuring instrument, not human error or lack of calibration.
- (c) One can estimate where deviations would fall between the marked divisions to increase the precision of the measurement.

### LIMIT OF PRECISION

**“The limit of precision of a measuring device is  $\pm \frac{1}{2}$  of the smallest division of measurement of the device.**

For example a meter scale marked in millimeter has a limiting precision of  $\pm 0.5$  mm or

$\pm 0.05$  cm. A vernier calipers that can measure nearest to 0.1 mm has a limiting precision of  $\pm 0.05$  mm or  $\pm 0.005$  cm. Therefore, if the length of a rod measured by a meter scale is 25.3 cm, the measurement can be written as  $25.3 \pm 0.05$  cm. This means that true value of length most likely lies between  $(25.3 \text{ cm} + 0.05 \text{ cm}) = 25.35 \text{ cm}$  and  $(25.3 \text{ cm} - 0.05 \text{ cm}) = 25.25 \text{ cm}$ . Sometimes limiting precision is taken equal to the least count of the device.

**Least count :** “The smallest measurement that can be taken accurately by a measuring instrument is called least count of that instrument”.

For example, a vernier callipers may have least count of 0.1 mm whereas a micrometer screw gauge have a least count of 0.01 mm.

## ERROR

**The difference between the true value and the measured value of a physical quantity is known as error or the uncertainty in a measurement is known as error.**

There are mainly two types of error

1. Systematic errors
2. Random errors or Non systematic errors.

**1. SYSTEMATIC ERRORS:** Due to known causes the errors that appear in a measurement is known as systematic error. For example,

- (i) In correct design or calibration of the instrument.
- (ii) Limitations of the method used for measurement.
- (iii) In correct reading or interpretation of the instrument
- (iv) lack of accuracy of the formula being used.

**2. RANDOM ERRORS:** These error occur due to unknown causes which is beyond the control of the experimenter. They arise even when the most careful measurement of the same physical quality is taken in the same way with the same equipment by the same experimenter. So these errors are inherently random in nature and hence they are to be treated by statistical method.

In order to minimise random errors, measurements are repeated many times and arithmetic mean of all measurements is taken as the true value of the measured quantity. If number of observations is made  $n$  time the random error is reduced to  $\frac{1}{n}$  times.

## ABSOLUTE ERROR

**The difference in the magnitude of true value and the measured value of a physical quantity is called absolute (actual) error.**

*i.e.*, Absolute error = true value of the physical quantity – measured value of the physical quantity.

The absolute errors can be positive in certain cases and negative in certain other cases.

Let  $A$  be a physical quantity which is measured  $n$  times and let the measured values are  $A_1, A_2, A_3, \dots, A_n$ .

$$\therefore \text{Arithmetic mean} = \frac{A_1 + A_2 + A_3 + \dots + A_n}{n}$$

or 
$$A_m = \frac{1}{n} \sum_{i=1}^{i=n} A_i$$

Thus, the arithmetic mean  $A_m$  is taken as the true value of the quantity. According to the definition, absolute errors is the individual measured values of the quantity are

Absolute error, 
$$\begin{aligned} \Delta A_1 &= A_m - A_1 \\ \Delta A_2 &= A_m - A_2 \\ \Delta A_3 &= A_m - A_3 \\ &\dots\dots\dots \\ &\dots\dots\dots \\ \Delta A_n &= A_m - A_n \end{aligned}$$

**MEAN ABSOLUTE ERROR :** The arithmetic mean of all the absolute errors in the measured value is known as mean absolute error. It is denoted by  $\Delta A_{\text{mean}}$

i.e., 
$$\Delta A_{\text{mean}} = \frac{|\Delta A_1| + |\Delta A_2| + \dots + |\Delta A_n|}{n}$$

or, 
$$\Delta A_{\text{mean}} = \frac{1}{n} \sum_{i=1}^{i=n} |A_i|$$

It is also known as final absolute error.

∴ We can write

$$A = A_m \pm \Delta A_{\text{mean}}$$

Hence the measurement of the physical quantity lies between  $A_m + \Delta A_{\text{mean}}$  and  $A_m - \Delta A_{\text{mean}}$

**RELATIVE ERROR:** The ratio of mean absolute error to the mean value or true value of the quantity being measured is called relative error or fractional error.

i.e., 
$$\text{Relative error} = \frac{\text{Mean absolute error}}{\text{Mean value}}$$

or, 
$$\text{Relative error} = \frac{\Delta A_{\text{mean}}}{A_m}$$

**PERCENTAGE ERROR :** The relative error is expressed in percentage is called percentage error i.e., percentage of error =  $\frac{\Delta A_{\text{mean}}}{A_m} \times 100$ .

**Example:** A student measures the time period of oscillation of a simple pendulum. In successive measurements, the readings turn out to be 2.56 second, 2.63 second, 2.71 second, 2.42 second and 2.80 second. Find the absolute error, relative error and percentage error.

**Solution:** Given, the absorbed values of time period

$$t_1 = 2.56 \text{ s}, t_2 = 2.63 \text{ s}, t_3 = 2.71 \text{ s}, t_4 = 2.42 \text{ s} \text{ and } t_5 = 2.80 \text{ s.}$$

∴ The mean period of oscillation of a simple pendulum

$$t_m = \frac{2.56 + 2.63 + 2.71 + 2.42 + 2.80}{5} = \frac{13.12}{5}$$

$$= 2.624 \text{ s.}$$

∴ The mean time period of oscillation to the second decimal place,  $t_m = 2.62 \text{ s}$ .

Now, the absolute errors in the each measurement are

$$t_m - t_1 = 2.62 - 2.56 = + 0.06 \text{ s}$$

$$t_m - t_2 = 2.62 - 2.63 = - 0.01 \text{ s}$$

$$t_m - t_3 = 2.62 - 2.71 = + 0.09 \text{ s}$$

$$t_m - t_4 = 2.62 - 2.42 = + 0.20 \text{ s}$$

$$t_m - t_5 = 2.62 - 2.80 = - 0.18 \text{ s}$$

∴ Mean absolute error

$$\Delta t_{\text{mean}} = \frac{0.06 + 0.01 + 0.09 + 0.20 + 0.18}{5} = \frac{0.54}{5} \text{ s}$$

$$= 0.11 \text{ second.}$$

Time period of simple pendulum,  $t = (2.62 \pm 0.11) \text{ second}$ .

Therefore,  $t$  lies between  $(2.62 + 0.11) \text{ second}$  and  $(2.62 - 0.11) \text{ second}$ .

*i.e.*, 2.73 second and 2.51 second.

Now, the relative error

$$= \pm \frac{\text{Mean absolute error}}{\text{Mean value}} = \pm \frac{0.11}{2.62}$$

*i.e.*, Relative error = 0.041

And hence percentage error

$$= \text{Relative error} \times 100$$

$$= \pm 0.041 \times 100 = \pm 4.1\%. \quad \text{Ans.}$$

**SIGNIFICANT FIGURE :** Significant figure is the number digits used to express the measurement of a physical quantity such that the last digit in it is doubtful, but the rest all are accurate or assured.

For example, when a measured distance is 576.8 m, it has 4 significant figures 5, 7, 6 and 8. The digits 5, 7 and 6 are certain and reliable digits, while 8 is doubtful. Similarly the radius measured by screw gauge is 3.24 cm, it has three significant figures 3, 2 and 4. The digit 3 and 4 are certain and reliable while digit 4 is doubtful.

The larger the number of significant figures in a measurement the greater is the precision of the measurement and vice-versa.

**RULES FOR COUNTING THE NUMBER OF SIGNIFICANT FIGURES :** Following are the rules for determining the number of significant figures in a measurement.

- (i) All non-zero digits are counted, *e.g.*, 156.25 gram contains five significant figures.
- (ii) All the zeroes between the numerals 1 and 9 are counted, *e.g.*, 105.003 meter contains six significant figures.
- (iii) In a measurement involving decimal, the position of decimal is ignored.
- (iv) All the zeroes after the last numeral are counted.
- (v) All the zeroes before the first numeral are ignored.
- (vi) The powers of ten are not counted as significant figure.

**Significant figures in calculations :** During calculations the following rule is obeyed for identifications of the number of significant figures.

- (i) When adding or subtracting to find the numbers which is known to the fewest decimal places, then round the result to that decimal place.

**Example-**

$$21.398 + 406 - 2.9 = 424$$

3 Significant figure, rounded to the ones position.

- (ii) When multiplying or deriding numbers to find the numbers with the fewest significant figures, then round the result to that many significant figures.

**Example-**  $0.049622 \times \frac{32.0}{478.8} = 0.00331$

3 Significant figures.

- (iii) When raising a number of some power count the number's significant figures, then round the result to that many significant figures.

**Example-**  $(5.8)^2 = 33.64 = 34$  2 Significant figures

- (iv) Mathematical Constant do not influence the precision of any computation.

**Example-**  $2 \times \pi \times 4.00 = 25.1$

**Note:-** In order to avoid introducing errors during multi step calculations, keep extra significant figures for intermediate results then round properly when you reach the final result.

**For example, Find the area enclosed by a circle of a diameter 1.06 m to correct number of significant figures.**

**Solution:**

Given,  $r = \frac{D}{2} = \frac{1.06}{2} = 0.5 \text{ m}$

As we know, Area =  $\pi r^2 = 3.14 \times (0.5)^2 = 0.882026 \text{ m}^2 = 0.882 \text{ m}^2$

Rounded off to three significant figures since diameter contains only three significant figures.

### SOLVED NUMERICAL PROBLEMS

**Example 1. Calculate the volume of a cylinder with a diameter of 9.9 cm and a height of 13.5 cm.**

**Solution:** Volume of cylinder

$$V = \text{area of base} \times \text{height} = \pi \times r^2 \times h$$

$$= \pi \times \left(\frac{D}{2}\right)^2 \times h = \frac{22}{7} \times \left(\frac{9.9}{2}\right)^2 \times 13.5$$

$$= 3.14 \times 24.50 \times 13.5 = 1038.55 = 1.038 \times 10^3 \text{ cm}$$

Since the least precise quantity is the diameter and is known to 2 significant figures, therefore answer must be expressed two significant figures.

$\therefore V = 1.0 \times 10^3 \text{ cm}^3$  **Ans.**

**Example 2. 5.75 gram of the substance occupies 1.2 cc. Find the density of the substance to correct significant figures.**

**Solution :**  $\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{5.75}{1.2} = 4.7916 \text{ g/cc}$

Since the least precise quantity is the volume (1.2 cc) and is known to two significant figures, the answer must have two significant figures.

$$\therefore \text{Density} = 4.8 \text{ g/cc.}$$

**Example 3. Perform the following operation to correct number of significant figures,  $6.8 \times 10^4 \text{ s} + 3.1 \times 10^5 \text{ second}$ .**

**Solution:** As we know that to add quantities of different exponents, we must first express them with same exponent.

$$\therefore 6.8 \times 10^4 + 3.1 \times 10^5 = 6.8 \times 10^4 + 31 \times 10^4 = 37.8 \times 10^4 \text{ second}$$

Since the least precise term is known to one decimal place thus final result must be expressed to one decimal place.

After rounding off the answer is  $3.8 \times 10^5 \text{ second}$ .

**Example 4. Find the value of 10 joules on a system of unit which has 10 cm, 100g and 30 seconds as the fundamental units.**

**Solution:** Joule is the SI unit of work

Let  $n_1$  is the S.I. unit whereas  $n_2$  is the new unit.

SI Units	New system of units
$n_1 = 10\text{J}$	$n_2 = ?$
$M_1 = 1 \text{ kg}$	$M_2 = 100 \text{ g}$
$L_1 = 1 \text{ m}$	$L_2 = 10 \text{ cm}$
$T_1 = 1 \text{ s}$	$T_2 = 30 \text{ s}$

Now we know that,

$$[\text{Work}] = [F \times S] = [\text{ML}^2 \text{T}^{-2}] \quad \therefore n_1 [\text{M}_1]^a [\text{L}_1]^b [\text{T}_1]^c = n_2 [\text{M}_2]^a [\text{L}_2]^b [\text{T}]^c$$

Let,  $a = 1, b = 2, c = 2$

$$\begin{aligned} \therefore n_2 &= n_1 \left[ \frac{M_1}{M_2} \right]^a \left[ \frac{L_1}{L_2} \right]^b \left[ \frac{T_1}{T_2} \right]^c = 10 \left[ \frac{1 \text{ kg}}{100 \text{ g}} \right]^1 \left[ \frac{1 \text{ m}}{10 \text{ cm}} \right]^2 \left[ \frac{1 \text{ s}}{30 \text{ s}} \right]^{-2} \\ &= 10 \left[ \frac{1000 \text{ g}}{100 \text{ g}} \right]^1 \left[ \frac{100 \text{ cm}}{10 \text{ cm}} \right]^2 \left[ \frac{1 \cancel{\text{s}}}{30 \cancel{\text{s}}} \right]^{-2} = 10 [10]^1 [10]^2 \left[ \frac{1}{30} \right]^{-2} \\ &= 10 \times 10 \times 100 \times 900 = 9 \times 10^6 \text{ New units} \end{aligned}$$

$\therefore 10\text{J} = 9 \times 10^6 \text{ New units. Ans.}$

**Example 5. If the units of length and force be each increased four times, show that the unit of energy is increased sixteen times.**

**Solution:** We have unit of energy = Unit of force  $\times$  unit of distance  
 $= [\text{MLT}^{-2}] \times [\text{L}] = [\text{ML}^2 \text{T}^{-2}]$

Now if the unit of force and distance be made four times each they would be  $4 (\text{M L T}^{-2})$  and  $4 \text{ L}$ , respectively and therefore, the new unit of energy would, be  $4 \text{ M L T}^{-2} \times 4 \text{ L} = 16 [\text{ML}^2 \text{T}^{-2}]$ , which is 16 times  $\text{ML}^2 \text{T}^{-2}$ , the ordinary unit.

Thus we see that by increasing the unit of force and length four times each, the unit of energy is increased sixteen times. **Ans.**

**Example 6.** Test by the method of dimensions the accuracy of the relation  $t = 2\pi \sqrt{\frac{k^2 + l^2}{lg}}$  for the time period of a compound pendulum.

**Solution:** If the relation be correct, the dimensions of the terms on either side of the sign of equality must be the same.

Let us put the relation as

$$t = 2\pi \sqrt{\frac{k^2}{lg} + \frac{l^2}{lg}}$$

Now the dimensions of  $t = [T]$

Now the dimensions  $K^2 = [L^2]$

the dimensions of  $l = [L]$

the dimensions of  $g = [LT^{-2}]$

Therefore, the dimensions of the terms on the right hand side are

$$\begin{aligned} &= \sqrt{\frac{\cancel{L^2}}{\cancel{L} \cancel{L} T^{-2}} + \frac{\cancel{L}}{\cancel{L} T^{-2}}} = \sqrt{T^2 + T^2} = \sqrt{2T^2} \\ &= T\sqrt{2}. \quad \text{Ans.} \end{aligned}$$

**Example 7.** The circular scale of a spherometer is divided into 200 equal divisions, if its least count is 0.005 mm then what is the distance between two consecutive threads of the spherometer screw?

**Solution:** We know that the distance between two consecutive thread is known as pitch of the spherometer.

Now we know that

$$\text{Least count} = \frac{\text{Pitch}}{\text{No. of circular scale division}}$$

or,  $0.005 \text{ mm} = \frac{\text{Pitch}}{200}$

$\therefore$  Pitch =  $200 \times 0.005 \text{ mm} = 1.000 \text{ mm} = 1.00 \text{ mm}$ . **Ans.**

Hence, the distance between two consecutive threads of a spherometer is 1 mm.

**Example 8.** In a given slide callipers 10 divisions of its vernier coincides with its 9 main scale division. If one main scale division is equal to 0.5 mm then find its least count.

**Solution:**  $\therefore$  10 divisions of vernier scale = 9 main scale divisions

$$\begin{aligned} \therefore \quad 1 \text{ division of vernier scale} &= \frac{9}{10} \text{ main scale divisions} \\ &= \frac{9}{10} \times 0.5 \text{ mm} && \{\because 1 \text{ MSD} = 0.5 \text{ mm}\} \\ &= 0.45 \text{ mm} \end{aligned}$$

Now we know that

$$\text{Least count of a slide callipers} = \text{Value of 1 MSD} - \text{Value of VSD}$$

$$= 0.5 \text{ mm} - 0.45 \text{ mm} = 0.05 \text{ mm.}$$

Therefore the least count of slide callipers equal to 0.05 mm. **Ans.**

### MULTIPLE CHOICE QUESTIONS

- Which is a fundamental quantity? [JUT-2019]  
 (a) length (b) velocity (c) acceleration (d) force
- How many significant digits are in 0.04058? [SBTEJ-2018]  
 (a) 4 (b) 5 (c) 6 (d) 3
- A physical quantity is measured and the result is expressed as  $nu$  where  $u$  is the unit used and  $n$  is the numerical value. If the result is expressed in various units then  
 (a)  $n \propto \text{size of } u$  (b)  $n \propto u^2$  (c)  $n \propto \sqrt{u}$  (d)  $n \propto \frac{1}{u}$
- Which of the following set enter into the list of fundamental quantities in any system of units?  
 (a) Length, mass and velocity (b) Length, time and velocity  
 (c) Mass, time and velocity (d) Length, time and mass
- A dimensionless quantity  
 (a) never has a unit (b) always has a unit  
 (c) may have a unit (d) does not exist.
- A unitless quantity  
 (a) never has a non-zero dimension (b) always has a non- zero dimension  
 (c) may have a non-zero dimension (d) does not exist.
- The dimension  $ML^{-1}T^{-2}$  may corresponds to  
 (a) Work done by a force (b) Linear momentum  
 (c) Pressure (d) Energy per unit volume.
- Choose the in correct statement  
 (a) A dimensionally correct equation may be correct  
 (b) A dimensionally correct equation may not be correct.  
 (c) A dimensionally in correct equation may be incorrect.  
 (d) A dimensionally incorrect equation may be incorrect.
- Which of the following has no dimension?  
 (a) Angle (b) Work (c) Force (d) Speed
- The length of a rod is  $(11.05 \pm 0.05)$  cm. Which is the total length of two such rods?  
 (a)  $(22.10 \pm 0.15)$  cm (b)  $(22.10 \pm 0.10)$  cm  
 (c)  $(22.10 \pm 0.05)$  cm (d)  $(22.15 \pm 0.10)$  cm
- The dimensions of gravitational constant are  
 (a)  $[ML^2T^{-2}]$  (b)  $[M^{-1} L^{-2} T^{-2}]$  (c)  $[M^{-1} L^{+3} T^{-2}]$  (d)  $[ML^{-3} T^{-2}]$
- Which one of the following has the dimensions of pressure?  
 (a)  $[ML^{-1}T^{-2}]$  (b)  $[M^{-1} L^{-1} T^{-1}]$  (c)  $[ML^{-2} T^{-2}]$  (d)  $[ML T^{-2}]$
- The significant figure in 3400 is

- (a) 1                      (b) 2                      (c) 3                      (d) 4
14. Length can not be measured in  
(a) light year              (b) Micron              (c) fermi              (d) debye
15. The dimensions of energy are  
(a)  $[ML^2T^2]$               (b)  $[M^2 L^2 T^{-2}]$               (c)  $[M L T^{-2}]$               (d)  $[ML T^{-1}]$
16. The correct number of significant figures in 0.0003056 is  
(a) Six                      (b) Four                      (c) Seven                      (d) Eight
17. The unit of electric current is  
(a) Ampere                      (b) Coloumb                      (c) Faraday                      (d) Newton
18. 1 angstrom ( $\text{\AA}$ ) is equal to  
(a)  $10^{-5}$  m                      (b)  $10^{-6}$  m                      (c)  $10^{-8}$  m                      (d)  $10^{-10}$  m
19. A student measured the thickness of a glass slab using a spherometer with least count 0.001 cm. The correct listing is  
(a) 0.234 cm                      (b) 0.234 m                      (c) 0.230 mm                      (d) 2.34 cm
20. When the two jaws of a vernier calliper are in touch zero of vernier scale lies to the right of zero of main scale and coinciding vernier division is 3. If vernier constant is 0.1 mm, the zero correction is  
(a) + 0.03 mm                      (b) + 0.03 cm                      (c) - 0.03 cm                      (d) - 0.03 mm
21. If the error in the measurement of radius of a sphere is 2%, then the error in the determination of volume of the sphere will be  
(a) 6%                      (b) 4%                      (c) 8%                      (d) 10%
22. Parsec is the unit of  
(a) time                      (b) distance                      (c) frequency                      (d) acceleration
23. What is the percentage error in volume of a sphere, when error in measuring its radius is 2%?  
(a)  $\pm 2\%$                       (b)  $\pm 3\%$                       (c)  $\pm 4\%$                       (d)  $\pm 6\%$
24. Joule  $\times$  sec is the unit of  
(a) energy                      (b) momentum  
(c) angular momentum                      (d) power
25. Dimensional formula of force is  
(a)  $[M^0L^2T^{-2}]$                       (b)  $[ML T^{-2}]$                       (c)  $[ML^2T^{-2}]$                       (d)  $[ML^2T^{-1}]$
26. The dimensional formula of Plank's constant ( $h$ ) is  
(a)  $[ML^{-2}T^{-3}]$                       (b)  $[ML^2 T^{-2}]$                       (c)  $[ML^2T^{-1}]$                       (d)  $[ML^{-2}T^{-2}]$
27. The dimensions of velocity is  
(a)  $[M^0L^2T^{-2}]$                       (b)  $[M^0L^2 T^{-2}]$                       (c)  $[MLT^2]$                       (d)  $[M^0LT^{-1}]$
28. The dimensional formula of bulk modulus of elasticity is  
(a)  $[ML^{-2}T^{-2}]$                       (b)  $[M^1L^2 T^{-2}]$                       (c)  $[M^1L^2T^{-2}]$                       (d)  $[M^1L^{-1}T^{-2}]$
29. The dimensions of calories are  
(a)  $[ML^2T^{-2}]$                       (b)  $[ML^2 T^{-2}]$                       (c)  $[ML^{-2}T^{-1}]$                       (d)  $[ML^2T^{-1}]$
30. If the unit of length mass and time each be doubled, the unit of work is increased  
(a) Two times                      (b) Four times                      (c) Six times                      (d) No change
31. The dimensional formula of impulse

- (a)  $[MLT^{-2}]$                       (b)  $[MLT^{-1}]$                       (c)  $[ML^2T^{-1}]$                       (d)  $[M^2LT^{-1}]$
32. The unit of coefficient of thermal conductivity is  
 (a) Watt-kelvin-m                      (b) Watt/m-k                      (c) J/c                      (d) Joule
33. The dimensional formula of latent heat is  
 (a)  $[M^0L^2T^{-2}]$                       (b)  $[MLT^{-2}]$                       (c)  $[ML^2T^2]$                       (d)  $[ML^2T^{-1}]$
34. The dimensions of  $1/\sqrt{\mu_0\epsilon_0}$  the same as that of  
 (a) Velocity                      (b) Time                      (c) Capacitance                      (d) Distance
35. Which of the following has not been expressed in proper unit  
 (a) Stress/strain =  $N/m^2$                       (b) Surface tension =  $N/m$   
 (c) Energy =  $kg \times m/s$                       (d) Pressure =  $N/m^2$
36. According to Newton, the viscous force acting between liquid layers of area  $A$  and velocity gradient  $\Delta v/\Delta z$  is given by  $F = \eta A \frac{\Delta v}{\Delta z}$  where  $\eta$  is a constant called coefficient of viscosity, the dimension of  $\eta$  are  
 (a)  $[ML^2T^{-2}]$                       (b)  $[M^0L^0T^0]$                       (c)  $[ML^2T^2]$                       (d)  $[ML^{-1}T^{-1}]$
37. The dimensions of the quantities is one of the following pairs are same. Identify the pairs  
 (a) Torque and work                      (b) Angular momentum  
 (c) Energy and Young's modulus                      (d) Light year and frequency
38. Plane angle and solid angle are  
 (a) Primary fundamental unit                      (b) Secondary fundamental unit  
 (c) Supplementary units                      (d) Derived units.
39. By the surface, the solid angle subtended at the centre of a sphere, whose area is equal to the surface of the radius of the sphere is known as  
 (a) Radian                      (b) Steradian                      (c) Candela                      (d) Lux
40. At the centre, the plane angle subtended by an arc of a circle equal to the radius of the circle is known as  
 (a) Steradian                      (b) Candela                      (c) Lumen                      (d) Radian
41. Another name of fundamental units is  
 (a) Base units                      (b) Atoms  
 (c) The metric system                      (d) Letter symbol
42. Which of the following metric prefixes could replace  $10^{-9}$ ?  
 (a) nano                      (b) mega                      (c) kilo                      (d) micro
43. The S.I. unit for amount of substance is  
 (a) mole                      (b) mole fraction                      (c) kilogram                      (d) gram
44. Select the odd one out in the following measurement units  
 (a) kilogram                      (b) gram                      (c) meter                      (d) second
45. The metric system is also called as  
 (a) CGS                      (b) MKS                      (c) SI                      (d) None of these
46. What is the name of physical quantities which are independent of each other?  
 (a) Fundamental quantity                      (b) Derived quantity  
 (c) Numerical quantity                      (d) None of these
47. What is the standard unit for length?

- (a) meter                      (b) inch                      (c) kilometer                      (d) centimeter
48. Which of the quantity consists of unit as newton-second?  
(a) Impulse                      (b) Acceleration                      (c) Speed                      (d) Velocity
49. Which of the quantity consists of unit as Pascal?  
(a) Temperature                      (b) Pressure                      (c) Force                      (d) Impulse
50. Which one of the following units is a fundamental unit?  
(a) newton                      (b) ampere                      (c) watt                      (d) joule/sec
51. Which of the following quantity consists of SI unit as Hertz?  
(a) Charge                      (b) Force                      (c) Frequency                      (d) Power
52. What is the S.I. units of mass length and time respectively?  
(a) g, m and s                      (b) kg, cm and s                      (c) g, cm and s                      (d) kg, m and s
53. How many fundamental units are there?  
(a) 4                      (b) 6                      (c) 7                      (d) 8
54. What is the S.I. unit of angle?  
(a) Steradian                      (b) Candela                      (c) Radian                      (d) Degree
55. Which of the following is a common unit of a physical quantity in MKS and SI system?  
(a) Ampere                      (b) Kelvin                      (c) Mole                      (d) Joule/see
56. The fundamental unit which is common is FPS and MKS system is?  
(a) Foot                      (b) See                      (c) Kilogram                      (d) Pound
57. Which of the following is unit of length?  
(a) Lunar month                      (b) Kelvin                      (c) Candela                      (d) Light year
58. The physical quantity having units of mass is  
(a) Density                      (b) Momentum                      (c) Inertia                      (d) Moment of force
59. Which of the following system is a British system?  
(a) C.G.S. system                      (b) R.P.S. system                      (c) M.K.S. system                      (d) None of these
60. Which of the following is not a unit of time?  
(a) Second                      (b) Month                      (c) Year                      (d) Light year
61. Unit of strain is  
(a) m/s                      (b) kg m                      (c) no unit                      (d) Nm
62. How many significant figures are in 0.04058?  
(a) 4                      (b) 5                      (c) 6                      (d) 3
63. The volume of a cube of 1 side is 1 cm is equal to  
(a)  $10^{-6}$  m                      (b)  $10^{-3}$  m                      (c)  $10^{-9}$  m                      (d) None of these
64. 1 Meter is equal to  
(a)  $1.05 \times 10^{-16}$  ly                      (b)  $2.0 \times 10^{-6}$  ly                      (c)  $2.0 \times 10^{-10}$  ly                      (d) None of these
65. 1 light year (ly) is equal to  
(a)  $9.46 \times 10^{15}$ m                      (b)  $10 \times 10^{16}$ m                      (c)  $1.5 \times 10^8$ m                      (d) None of these
66. Which of the following is the most precise device for measuring length?  
(a) A vernier callipers with 20 divisions on the main scale  
(b) A snow gauge of pitch 1 mm and 100 divisions on the circular scale.

- (c) An optical instrument that can measure length to within a wave length of light  
(d) None of these.
67. State the number of significant figures in the following 6.320J  
(a) 1 (b) 4 (c) 3 (d) None of these
68. Which of the following time measuring devices is most precise?  
(a) A wall clock (b) A stop watch (c) A digital watch (d) An atomic clock
69. A physical quantity which has a unit but no dimension is  
(a) Plane angle (b) Strain (c) Mole (d) None of these
70. Mass is given by the relation  
(a) Velocity/acceleration (b) Force/velocity  
(c) Force/acceleration (d) None of these
71. A thin copper wire of length  $L$  increase in length by 2% when heated from  $T_1$  to  $T_2$ . If a copper cube having side  $10 L$  is heated from  $T_1$  to  $T_2$ , what will be the percentage error in area of one face of the cube?  
(a) 4% (b) 6% (c) 8% (d) None of these
72. Which of the following system of units is not based on units of mass, length and time alone?  
(a) SI (b) MKS (c) FPS (d) CGS
73. Which of the following is smallest unit?  
(a) Millimeter (b) Angstrom (c) Fermi (d) Meter
74. The dimensional formula of wave number is  
(a)  $[M^0 L^0 T^{-1}]$  (b)  $[M^{-1} L^{-1} T^0]$  (c)  $[M^0 L^{-1} T^0]$  (d)  $[M^0 L^0 T^0]$
75. Zero error of an instrument introduces  
(a) Systematic error (b) Random error  
(c) Both (d) None of these
76. A vernier callipers has 20 divisions on the vernier scale which coincide with 19 divisions on the main scale. The least count of the instrument is 0.1 mm, the main scale divisions are of  
(a) 0.5 mm (b) 1 mm (c) 2 mm (d) 1/4 mm
77. A student measured the diameter of a wire using a screw gauge with least count 0.001 cm and listed the measurements. The correct measurement is  
(a) 5.3 cm (b) 5.32 cm (c) 5.320 cm (d) 5.3200 cm
78. A spring balance is used to measure  
(a) The weight of a body (b) The mass of a body  
(c) Both mass and weight of a body (d) None of the above
79. A physical quantity is one of which  
(a) Cannot be measured (b) Can be measured  
(c) Is a scalar quantity (d) Is a vector quantity
80. The volume of are sphere is 1.76 cc the volume of 25 such spheres to correct significant figures is  
(a) 44.00 cc (b) 44.0 cc (c) 44 cc (d)  $0.44 \times 10^2$  cc

81. The length of a rod is measured with ordinary meter rod and is found to be exactly 3 cm. The measurement will be recorded as  
 (a) 3 cm (b) 3.0 cm (c) 3.00 cm (d) 3.000 cm
82. One student the length of a rod with a ruler and find it to be 6.8 cm. The accuracy in measurement is about  
 (a) 3% (b) 5% (c) 1.5% (d) 10%
83. The length of a rod is given 8.1 cm. The least count of the measuring device is  
 (a) 0.1 mm (b) 0.01 mm (c) 0.001 mm (d) 1 mm
84. The errors in measuring the mass and volume of a body are 5% and 2% respectively. The error in measuring density will be  
 (a) 7% (b) 10% (c) 3% (d) 2.5%
85. The dimension of  $\sin \theta$  is  
 (a)  $[L^2]$  (b)  $[M]$  (c)  $[ML]$  (d) No dimension
86. A physical quantity P is given by  

$$P = ab^2c^3d^4$$
 The percentage error in the measurement of  $a, b, c$  and  $d$  is 0.5% each. The error in the measurement of P will be  
 (a) 2.5% (b) 8% (c) 5% (d) 6%

## ANSWERS

- |           |         |         |         |         |         |
|-----------|---------|---------|---------|---------|---------|
| 1. (a)    | 2. (b)  | 3. (d)  | 4. (d)  | 5. (c)  | 6. (a)  |
| 7. (c, d) | 8. (c)  | 9. (a)  | 10. (b) | 11. (c) | 12. (a) |
| 13. (b)   | 14. (d) | 15. (a) | 16. (b) | 17. (a) | 18. (d) |
| 19. (a)   | 20. (c) | 21. (a) | 22. (b) | 23. (d) | 24. (c) |
| 25. (c)   | 26. (c) | 27. (a) | 28. (d) | 29. (a) | 30. (a) |
| 31. (b)   | 32. (b) | 33. (a) | 34. (a) | 35. (c) | 36. (d) |
| 37. (a)   | 38. (c) | 39. (b) | 40. (d) | 41. (a) | 42. (a) |
| 43. (a)   | 44. (b) | 45. (b) | 46. (a) | 47. (a) | 48. (a) |
| 49. (b)   | 50. (b) | 51. (c) | 52. (d) | 53. (c) | 54. (c) |
| 55. (d)   | 56. (b) | 57. (d) | 58. (c) | 59. (b) | 60. (d) |
| 61. (c)   | 62. (a) | 63. (a) | 64. (a) | 65. (a) | 66. (c) |
| 67. (a)   | 68. (d) | 69. (a) | 70. (c) | 71. (a) | 72. (a) |
| 73. (c)   | 74. (c) | 75. (a) | 76. (b) | 77. (c) | 78. (a) |
| 79. (b)   | 80. (b) | 81. (b) | 82. (c) | 83. (d) | 84. (a) |
| 85. (d)   | 86. (c) |         |         |         |         |

## SHORT AND LONG TYPE QUESTIONS

1. What do you understand by fundamental and derived units?
2. Define the term – accuracy, precision, absolute error and percentage error. [SBTEJ-2018]
3. What is the importance of measurement in science and engineering?
4. What are the desirable features of fundamental units?
5. What is a coherent system of units?

6. Define astronomical unit light year and parsec. How they are related?
7. What is the difference between nm, mN and Nm?
8. If  $f = a^2$ , relative error in  $f$  would be how many times the relative error in  $a$ ?
9. Define dimensions of a physical quantity. What is dimensional formula?
10. Explain the principle of homogeneity of dimensions. Find its uses.
11. What are the limitations of dimensional analysis?
12. Derive expression using the method of dimensions, for the time period of a simple pendulum.
13. What is SI unit of length? Why is this unit defined in terms of wavelength of light radiation?
14. What is system of unit? Explain.
15. State and explain unit of a physical quantity.
16. What are the needs of measurement in engineering and science?
17. Define the term-accuracy precision and error with example, explain absolute error, relative error and percentage error.
18. What do you understand by the term-least count of a measuring instrument?
19. What is significant figures?  
Write the rules to identify significant figures. Find the number of significant figures of the following:  
(a) 1.080                      (b) 0.0018                      (c) 1.08                      (d)  $5.98 \times 10^{12}$
20. Define astronomical unit, light year and par sec. How are they related? Name three physical quantities which have same dimensions.
21. If velocity, time and force are chosen as base quantities then find the dimensions of mass.
22. Which of the following is the most precise device for measuring length and why?  
(a) A vernier callipers with 20 divisions on the main scale.  
(b) A screw gauge of pitch 1 mm and 100 divisions on the circular scale.  
(c) An optical instrument that can measure length to within wavelength of light?
23. Write the rules in counting significant figures in a calculation with example.

# A Textbook of Engineering Physics-I

As Per the Latest Syllabus of Diploma in Engineering Courses under  
Jharkhand University of Technology, Ranchi

## About the Book:

This book has been especially written for Diploma Engineering students of First Semester of All Branches. The organization and contents of this book are methodically and systematically arranged, though this book follows the sequence of topics as prescribed in the latest syllabus for Diploma Engineering by **Jharkhand University of Technology, Ranchi for Polytechnics** in Jharkhand State. The author has endeavoured to present this book in a lucid manner maintaining continuity of the subject throughout the text to minimise the need of students to make cross references.

## Salient Features:

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- Multiple Choice Questions with Answers, Short and Long Type Questions and Solved and Unsolved Numerical Problems at the end of each chapter.
- Emphasis on the Engineering based applications.

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